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Kheraiceras Spath (Ammonoidea)—new forms and records from the Middle Jurassic sequence of the Indian Subcontinent

SUDIPTA K. JANA, SUBHENDU BARDHAN and SUBRATA K. SARDAR

Department of Geological Sciences, Jadavpur University, Calcutta 700–032, India
(corresponding author: Bardhan, s_bardhan01@yahoo.co.uk)

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Abstract. ***Kheraiceras*** **Spath reached its peak during the Late Bathonian-Early Callovian and achieved a wide biogeographic distribution during that interval. The genus speciated rapidly and is represented in the fossil record by many species. The present endeavour provides a full taxonomic account of six species, of which five are from Kutch, western India. The sixth, *K. noetlingi* sp. nov., is based on the specimen described as '*Sphaeroceras*' cf. *bullatum* d'Orbigny by Noetling (1896) from Baluchistan, Pakistan. Among the five Kutch species one has also been found in Baluchistan. We know little about specific dimorphism in *Kheraiceras*. In at least three instances dimorphic pairs have been matched. Of the six species of *Kheraiceras* described herein three are new and two are new records. They are: *Kheraiceras cosmopolitum*, *K. bullatum*, *K.* cf. *hannoveranum*, *K. spathi* sp. nov., *K.* sp. A, and *K. noetlingi* sp. nov. Like many other biota, including other ammonites, *Kheraiceras* speciation is marked by a high degree of endemism in the Kutch Sea, which extended up to Baluchistan. The endemism in this newly opened basin is due to the transgressions resulting from the fragmentation of Gondwanaland.**

Key words: ***endemism, Indian Subcontinent, Kheraiceras*****, Middle Jurassic, migration, sexual dimorphism**

Introduction

The genus *Kheraiceras* Spath, 1924 of the family Tulitidae has been thought to evolve from *Bullatimorphites* Buckman, 1921. Unlike its probable ancestor, *Kheraiceras* has a wide biogeographic distribution along the margins of the Tethys and the Pacific including Indonesia, Mexico and South America (Donovan *et al.*, 1981; Mangold, 1984; Riccardi *et al.*, 1989; Sandoval *et al.*, 1990; Westermann, 1993). The genus has not been reported, however, from the Boreal or Subboreal Provinces. From the distribution patterns it appears that *Kheraiceras* is longitudinally widespread and latitudinally more restricted to the palaeotropics and subtropics (see also Westermann and Callomon, 1988). It shows strong facies control, since most of its species are found mainly in calcareous facies deposited in shallow seas (Arkell, 1952; Bardhan *et al.*, 1988). *Kheraiceras* is of great stratigraphic value because of its short temporal distribution, although its biostratigraphic potentialities have not been fully explored (see Bardhan *et al.*, 1999). *Kheraiceras* ranges in age from Late Bathonian to Late Callovian (Hahn, 1969, 1971), but was at its peak during the Late Bathonian and Early Callovian when many other biostratigraphically important taxa, e.g. *Macrocephalites* Zittel, 1884 and *Reineckeia* Bayle, 1878 also flourished.

In the present endeavour, we have made a taxonomic study of six *Kheraiceras* species, among which three are new and two have not been described previously from the subcontinent. Dimorphism is now considered to be very important in understanding evolution within a lineage and must be taken into account in phylogeny. Although dimorphism in *Kheraiceras* is evident, little is known about specific dimorphic pairs (for details see Bardhan *et al.*, 1994, 1999). In the present study we have distinguished dimorphic pairs in three species. Besides, there are two new microconchs and one macroconch species whose counterparts are still unknown. So far *Kheraiceras* is described in the literature mainly by macroconchs and microconchs are often rare. We have plentiful microconch specimens with a well preserved peristome showing apertural modifications. They are described herein.

The measurements of the types and other specimens of the present collection (abbreviated as below) are in mm. D=diameter; H=whorl height; W=whorl width; U=umbilical diameter.

Repository.—Curatorial Division, Geological Survey of

India, Calcutta (GSI); The Indian Museum, Calcutta; Department of Geological Sciences, Jadavpur University, Calcutta, India (JUM).

Previous Study

There are only a few reports of *Kheraiceras* from the Indian subcontinent. Waagen's (1875) "*Stephanoceras bullatum*" d'Orbigny, 1846 which Spath (1924) subsequently made the type species of *Kheraiceras*, i.e., *K. cosmopolitum*, comes from the Golden Oolite of Keera, Kutch. Recently many specimens of this species have been collected from Kutch, and the intraspecific variability and dimorphism of this species have been firmly established (Bardhan *et al.*, 1994). Noetling (1896) described a large single specimen as *'Sphaeroceras'* cf. *bullatum* (pl. 6, figs. 2, 2a) from the Polyphemus Limestone bed of Mazardrik, Baluchistan. Although it resembles *Kheraiceras hannoveranum* (Roemer, 1911) from the Late Bathonian of Europe (Westermann and Callomon 1988), novel traits distinguish it and is described here as a new species. Spath (1931) reported *K.* aff. *cosmopolitum* from his Macrocephalus Zone of Jumara, Kutch, which is represented by a complete microconch resembling closely the one of our present species, *K. spathi* <m> and has been synonymised with it. Kanjilal (1978) reported *Kheraiceras probullatum* from Kutch which is now considered to be a variant of *Macrocephalites formosus* (Sowerby, 1840) (see Pandey and Westermann, 1988). *K.* ex. gr. *platystoma* reported by Bardhan and Datta (1987) from Jumara is now considered to be an extreme depressed variant of *K. cosmopolitum*. Krishna *et al.* (1987) illustrated but did not describe a specimen as a microconch of *K. cosmopolitum* from the Golden Oolite of Keera. It appears, however, from the figure to be an adult macroconch of *K. bullatum* with a partially preserved body chamber. Bardhan *et al.* (1988) described *Bullatimorphites* sp. from Jumara which is in fact a *Kheraiceras* species with a less depressed inner whorl and strong, coarse ribbing persisting on the adult body chamber. It has been redesignated here as *K.* cf. *hannoveranum* (see also Callomon, 1993; Jain *et al.*, 1996). Panday and Westermann (1988) reported a single specimen of *Bullatimorphites* (*Kheraiceras*?) n. sp. A from the Middle (?) Bathonian of Patcham 'island', Kutch. It has peculiar *Bullatimorphites*-like inner whorls and a *Kheraiceras*-like eccentrically coiled body chamber.

The spatio-temporal distribution of *Kheraiceras* reveals its relatively narrow stratigraphic but wide biogeographic distributions. Yet little attention has been paid to its biostratigraphic potentialities except in Submediterranean France. In a previous attempt we have proposed a new biozonation scheme of the Upper Bathonian-Lower Callovian sequence of Kutch based on different stratigraphic ranges of *Kheraiceras* and other important time-diagnostic taxa such as *Macrocephalites, Reineckeia* etc. (Bardhan *et al.*, 1999). An attempt has also been made for regional standard chronostratigraphy and interprovincial correlation.

Stratigraphy

Species of *Kheraiceras* are distributed throughout the entire Callovian sequence of the basal Chari Formation in Kutch. One species straddles into the uppermost Batho-

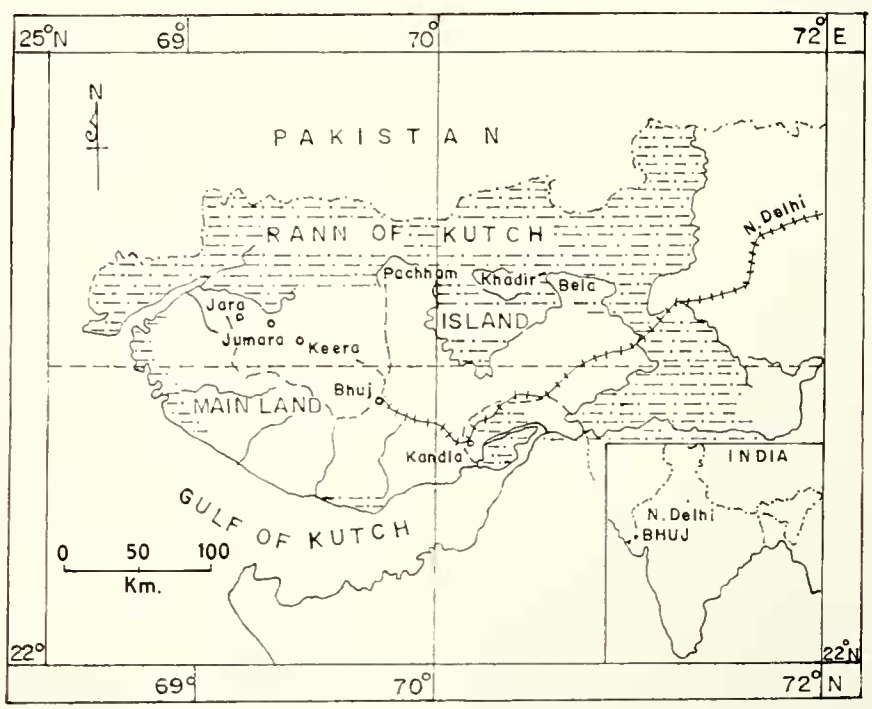


Figure 1. Geographic location of Kutch with Keera and Jumara, the type area of the Chari Formation. The patterned area is the Rann of Kutch.

nian bed in Jumara. The Chari Formation is a regionally persistent, highly fossiliferous unit and constitutes one of the four principal divisions of the Kutch Mesozoic (for details see Biswas, 1977; Mitra *et al.*, 1979; Krishna, 1984). It represents a near-continuous section ranging from the Upper Bathonian through the entire Callovian and Oxfordian. There are, however, reports of condensation of the sequence and time-averaging of fauna during the Oxfordian (Fürsich *et al.*, 1992; Halder and Bardhan, 1996). The Chari Formation represents a heterolithic facies consisting of shale, limestone and sandstone. The carbonate facies which yields the present *Kheraiceras* specimens is occasionally oolitic and is more dominant in the lower part of the sequence. The partially exposed, underlying Patcham Formation at Jumara is on the other hand predominantly calcareous, consisting of coral biostromes and limestone-marl alternations. Judging from the faunal associations and sedimentological evidence, these two formations are considered to be the product of a shallow-marine environment (Biswas, 1991; Datta, 1992; Fürsich and Oschmann, 1993).

The present *Kheraiceras* species have been systematically collected from different limestone beds of Jumara and Keera in the mainland of Kutch (Figure 1). Jumara is the stratotype of the Chari Formation and Keera is the type locality of *Kheraiceras cosmopolitum*. Stratigraphic occurrences of *Kheraiceras* species in the Jumara and Kerra sections is shown in Figure 2.

All species of *Kheraiceras* described herein restrictedly occur within the zones spanning Upper Bathonian to Lower Callovian (Figure 3). Although these zones are based mainly on endemic Kutch ammonites, discoveries (e.g., Kayal and Bardhan, 1998) of some well time-diagonosed short-ranging taxa have made possible broad interprovincial correlation with other *Kheraiceras*-bearing provinces (for detailed discussion on age and correlation see Bardhan *et al.*, 1999).

Kheraiceras cf. *hannoveranum* is also known from

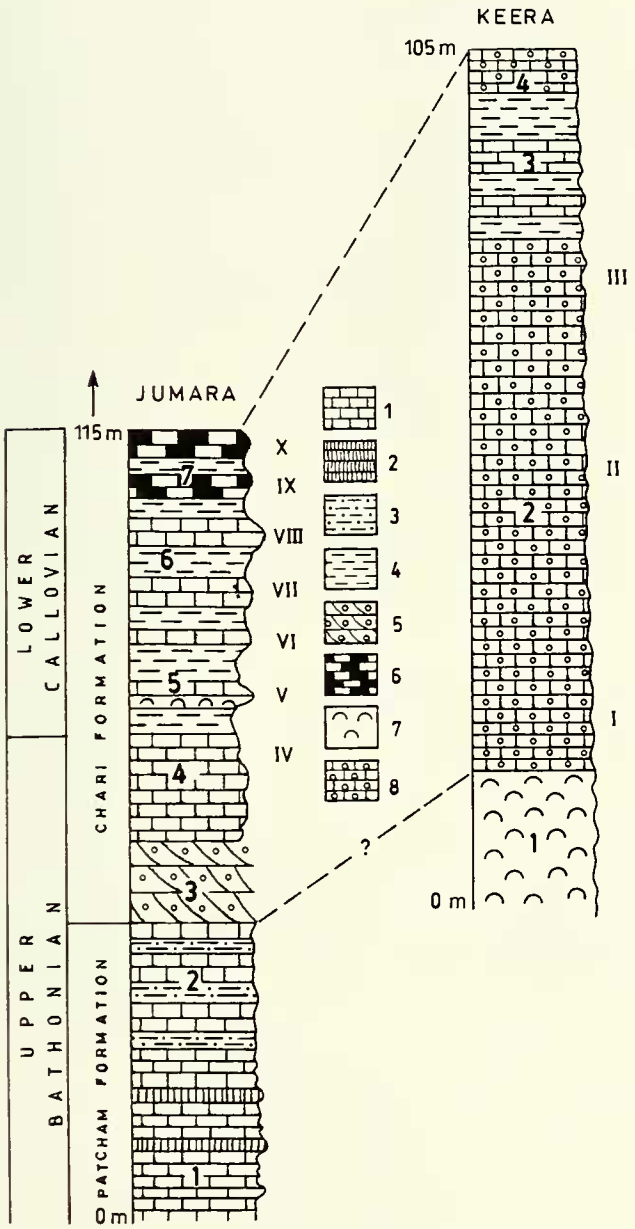


Figure 2. Stratigraphic sections at Jumara and Keera, Key. 1. white, cream or brown-coloured limestone; 2. coral biostrome; 3. marl; 4. shale; 5. cross-stratified, lenticular, green, oolitic limestone; 6. grey shelly limestone with thin alternating bands of red or white limestone and grey shale; 7. bioclastic grainstone; 8. oolitic limestone. Occurrences of different *Kheraiceras* species are indicated by horizon nos. (I–X).

AGE	ZONE	SUBZONE	FAUNAL HORIZON	SPECIES
EARLY CALLOVIAN	FORMOSUS	SEMILAEVIS	Nothocephalites semilaevis	
		FORMOSUS	M.formosus	
			Kamptokephalites lamellosus	
		DIADEMATUS	Kampt. dimerus	
			K.bullatum	
			I. diadematus	
		TRANSITORIUS	Kheraiceras cosmopolitum	
			I.transitorious	
LATE BATHONIAN	CHRYSOOLITHICUS	MADAGASCARIENSIS	M.madagascariensis	
			Sivajiceras congener	
		CHRYSOOLITHICUS	Indocephalites chrysoolithicus	
	TRIANGULARIS	TRIANGULARIS	Macrocephalites triangularis	
		HIANS	Proceriteshians	

K. sp.A.
K.cosmopolitum
K.bullatum
K.cf.hannoveranum
K.spathi

Figure 3. Range chart of different species of *Kheraiceras* in Kutch. Zones and Subzones are after Bardhan *et al.* (1999).

Baluchistan. Another new species described here, *Kheraiceras noetlingi*, has been found only in Baluchistan. Both come from the Polyphemus Limestone, Mazardrik, Baluchistan.

Kheraiceras Faunal Associations

Kheraiceras, though it ranges from Late Bathonian to Late Callovian (Hahn, 1969), is more diverse in Early Callovian, when other biostratigraphically important genera e.g., *Macrocephalites* Zittel and *Reineckeia* Bayle, also underwent adaptive radiation. In Submediterranean France *Kheraiceras* is closely associated with reineckeiids in the Lower Callovian beds, but macrocephalitids are rare (Cariou, 1984). In England, this part is marked by diverse macrocephalitid species but *Kheraiceras* and reineckeiids are absent (Callomon *et. al.*, 1988). Kutch, on the other hand, includes ammonites of all these three groups and thus provides a unique opportunity for high resolution of biostratigraphic zonation and interprovincial chronostratigraphic correlation.

Recently Bardhan *et. al.* (1999) proposed biostratigraphic zonations within the Bathonian-Callovian Stages of Kutch (Figure 3). The faunal horizons are not found in every section, but the subzones are regionally persistent and can be easily recognised for their characteristic ammonite assemblages in all the sections in the mainland of Kutch.

Kheraiceras species are distributed throughout these assemblages except for the lowest one, i.e., the Triangularis Subzone. Different *Kheraiceras* species have different biostratigraphic ranges and like macrocephalitids, they are more diverse in the lowest Early Callovian. A brief summary of the faunal association of each *Kheraiceras* species is given here (Figure 4). The relative abundance of other important ammonite species is discussed and a possible age correlation based on time-diagnostic or equivalent taxa is indicated.

The only *Kheraiceras* species described from outside Kutch is *K. noetlingi* sp. nov. It comes from the Polyphemus Limestone, Mazardrik, Baluchistan (Noetling, 1896). It is associated with *Macrocephalites triangularis* 'group', *Clydoniceras baluchistanense* (Spath) and *Choffatia (Homeoplanulites)* (Spath). This faunal association indicates a Late Bathonian age (see also Westermann and Callomon, 1988).

K. cf. *hannoveranum* first appeared in the Madagascariensis Subzone of the Chrysoolithicus Zone in Kutch. It resembles the lectotype coming from the Upper Bathonian Orbis Zone of Germany. In the Madagascariensis Subzone, *Macrocephalites madagascariensis* is particularly abundant. It resembles *M. verus* (Buckman) in Europe which comes from the lowermost Callovian (Cariou, 1984; Callomon *et al.*, 1988). Another abundant macrocephalitid species is *Indocephalites chrysoolithicus* (Spath). *Sivajiceras congener* is also abundant while *Choffatia* sp. and *Oxycerites (Paroxycerites?)* sp. are less common. *K.* cf. *hannoveranum* also continues to the next assemblage, i.e., the Transitorius Subzone of the lowest Early Callovian where it co-occurs with diverse macrocephalitids, e.g., *Indocephalites transitorius, I. kheraensis, I. diadematus, Pleurocephaites elephantinus, Kamptokephalites lamellosus* and

Ammonite association	Kheraiceras species	Other important ammonite species																							
		Macrocephalites madagascariensis	Macrocephalites formosus	Indocephalites transitorius	Indocephalites kheraensis	Indocephalites chrysoolithicus	Indocephalites diadematus	Pleurocephalites elephantinus	Dolikephalites subcompressus	Kamptokephalites lamellosus	Kamptokephalites dimerus	Kamptokephalites magnumbilicatus	Nothocephalites semilaevis	Nothocephalites asaphus	Eucycloceras eucyclum	Subkossmatia opis	Reineckeia tyrranniformis	Reineckeia anceps	Collotia oxyptycha	Choffatia cobra	Choffatia pardagatus	Choffatia recuperoi	Choffatia sp.	Sivajiceras congener	Oxycerites (Paroxycerites?) sp.
Nothocephalites semilaevis	K. cosmopolitum		●		o	o	x	x	o	o	o	x	●	x	x	x	x	x	x	o	o	●			
Macrocephalites formosus	K. cosmopolitum K. sp. A		●		●	o	o	o	●	●	●	x					x					x			
Macrocephalites diadematus	K. cosmopolitum K. bullatum		o		o	o	●	●	o	o	●	x										x	x		
Indocephalites transitorius	K. cosmopolitum K. bullatum, K. spathi K. cf. hannoveranum		o	●	o	o	o	o	o	o	o												x		
Macrocephalites madagascariensis	K. cf. hannoveranum	●				●																	x	●	x

● abundant, o common, x rare

Figure 4. Biostratigraphic distribution of *Kheraieras* species in Kutch in association with other important ammonites.

Dolikephalites subcompressus, Macrocephalites formosus. Besides, other *Kheraiceras* species e.g., *K. cosmopolitum, K. bullatum, K. spathi* are also found from this level.

K. cosmopolitum is the most abundant species of *Kheraiceras* and an endemic form. It has a longer stratigraphic distribution spanning the entire Formosus Zone of the Lower Callovian. This zone can be approximately correlated with the Lower Callovian Macrocephalus and Gracilis Zones of France (see also Krishna and Westermann, 1987; Bardhan *et. al.*, 1999). It is more frequent in the Formosus Subzone, where it is associated with abundant *Macrocephalites formosus, Indocephalites kheraensis, Kamptokephalites dimerus, Kamptokephalites lammellosus, Dolikephalites subcompressus,* and rare *Choffatia recuperoi, Reineckeia tyrraniformis.* In the superjacent Semilaevis Subzone, *K. cosmopolitum* is associated with abundant *Nothocephalites semilaevis, Choffatia recuperoi. Collotia oxyptica, Eucyclocers eucyclum, Subkossmatia opis* and *Nothocephalites asaphus* are rare at this level. Judging by this faunal association, the upper limit of *K. cosmopolitum* can reasonably be placed at the uppermost Early Callovian. *K. spathi* sp. nov. comes from the level immediately above the Bathonian-Callovian boundary. This horizon yields diverse *Kheraiceras* species e.g., *K. cosmopolitum, K.* cf. *hannoveranum, K. bullatum.* The important macrocephalitids are *I. transitorius, I. chrysoolithicus, I. diadematus, P. elephantinus* etc.

K. bullatum appeared slightly above the base of the Lower Callovian, spanning the upper part of the Transitorius and the entire Diadematus Subzones. Here it is associated with *K. cosmopolitum* and typical members of the faunal assemblage such as *I. diadematus, P. elephantinus, K. dimerus,* etc. This faunal association indicates a late appearance of *K. bullatum* in Kutch because it is already known from the Late Bathonian of Europe as well as South America (see Riccardi *et al.*, 1989; Sandoval *et al.*, 1990). We agree with Krishna and Cariou (1990) who correlated *K. bullatum*-bearing horizons of Kutch approximately with the upper Herveyi Zone and Bullatus Zone of France on the basis of common associated taxa.

K. sp. A is represented by a single microconchiate specimen from the Formosus Subzone, which marks the disappearance of *K. bullatum.* It is associated with *K. cosmopolitum* and abundant *M. formosus, K. dimerus, K. lamellosus* and *D. subcompressus.*

Systematic Palaeontology

Superfamily Perisphinctaceae
Family Tulitidae Buckman, 1921
Genus ***Kheraiceras*** Spath, 1924

Type species.—*Sphaeroceras cosmopolitum* Parona and Bonarelli 1895; original desgination.

Kheraiceras cosmopolitum
(Parona and Bonarelli, 1895)

Figures 5.1–5.4; 6c

Holotype.—GSI Type No. 2009. Internal mould with partial shell remains, adult macroconch with last quarter of body chamber missing, from Golden Oolite of Keera.

Material.—In addition to the holotype, one macroconch (JUM/J/5) and two microconchs (JUM/J/2 and JUM/J/6) have been studied. All of them come from Jumara. The macroconch is an adult specimen with thin shell and last quarter of the body chamber missing, from Horizon V, Bed 5. The microconchs are almost complete, both coming from Bed 7; JUM/J/2 with terminal constriction present at flank and abraded on one side, from Horizon IX; JUM/J/6 with thin shell, from Horizon X.

Diagnosis.—Sphaeroconic, whorls extremely depressed and to a maximum in phragmocone, W/H ratio=2.8; body chamber occupies more than three-fourths of last whorl; beginning of body chamber marked by sudden whorl contraction and umbilical uncoiling following first a straight centrifugal line and then turning suddenly inwards; ribbing feeble in internal mould, disappears more rapidly near umbilicus than venter on body chamber, last seen at a diameter of 58 mm; umbilicus small, deep, umbilical wall gradually becomes steeper; flanks extremely short; septal suture with typically shallow tulitid U_2.

Description.—Detailed systematic description of macroconch, microconch, their synonymy and stratigraphic distribution have already been given in Bardhan *et al.* (1994).

Occurrence.—*Kheraiceras cosmopolitum* is an endemic Kutch species. The holotype comes from the Golden Oolite (Bed 2), Keera. JUM/J/5 is collected from Horizon V, Bed 5, Jumara. JUM/J/2 and JUM/J/6 come from Horizon IX and X respectively of Bed 7, Jumara.

Kheraiceras bullatum (d'Orbigny, 1846)

Figures 5.5a,b; 6a,b; 7.1–7.6; 8.1a–c; 9

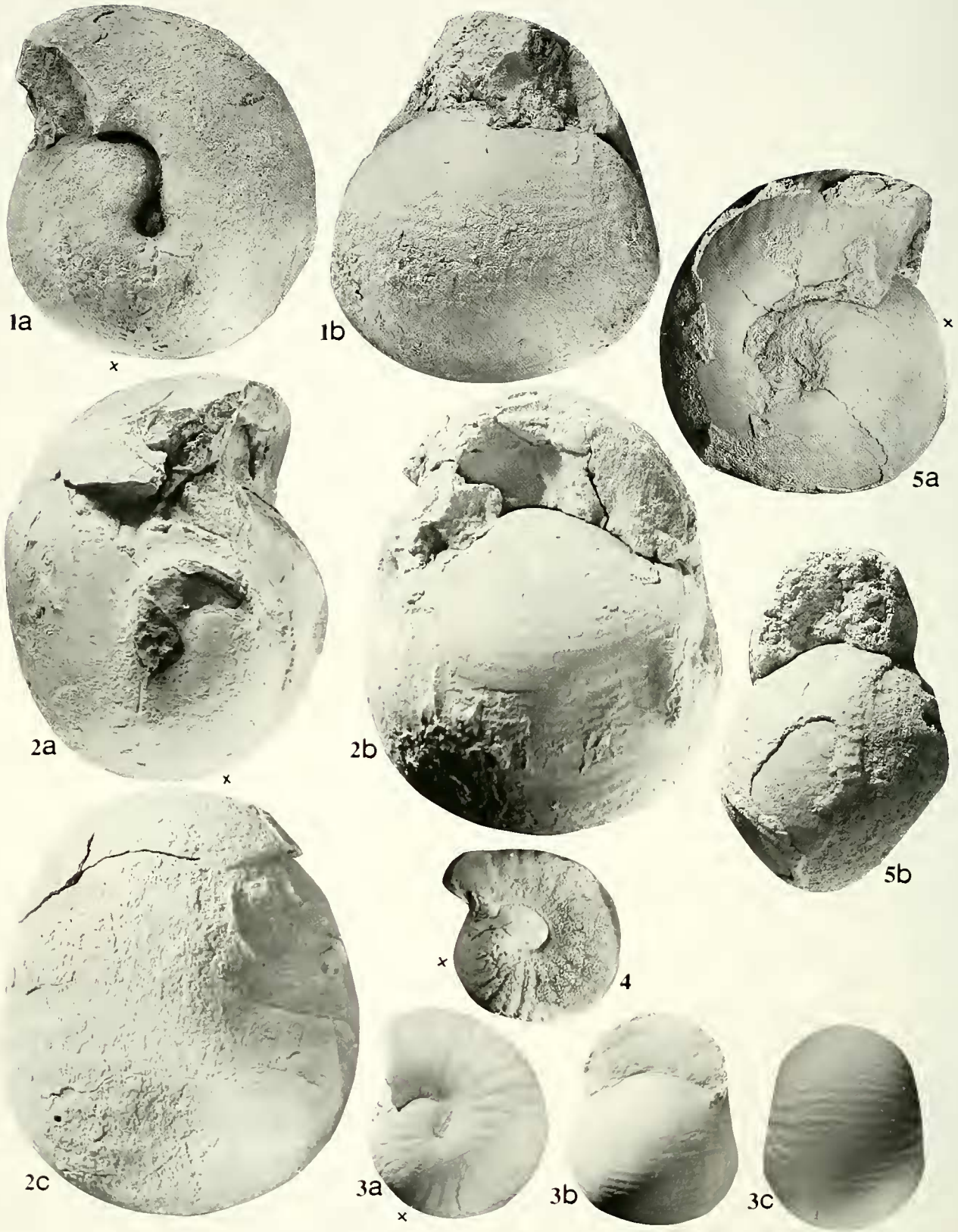
Macroconch.—

1846 *Ammonites bullatus* d'Orbigny, pl. 142, fig. 1, 2.
1954 *Bullatimorphites bullatus* (d'Orbigny). Arkell, text-fig. 34.
1958 *Kheraiceras bullatus* (d'Orbigny). Westermann, pl. 22, fig. 1a–b.
1984 *Bullatimorphites (Kheraiceras) bullatus* (d'Orbigny). Westermann, Corona and Carrasco, pl. 2, fig. 8a–b.
1987 *Kheraiceras cosmopolita* Krishna, Cariou and Enay, p. 4, pl. 1, fig. 6.
1990 *Kheraiceras bullatum* (d'Orbigny). Krishna and Cariou, p. 112.

Macroconch and microconch.—

1999 *Kheraiceras bullatum* (d'Orbigny). Bardhan, Sardar and Jana, pl. 1, figs. 5–6.

Material.—Seven macroconch specimens, mostly adults, internal moulds with aperture missing. All come only from Bed 2, Keera; JUM/K/8-12, JUM/K/17 from lower horizon (Horizon I) and a near complete small variant, JUM/K/13, from upper level (Horizon II). Four microconchs with shell remains come only from Jumara; JUM/J/12 and JUM/J/13 with flared collar from Bed 6 (Horizon VII); JUM/J/14 with last quarter of body chamber missing, from Bed 5 (Horizon VI); JUM/J/11 near complete, abraded on one side, from basal part of Bed 7 (Horizon IX).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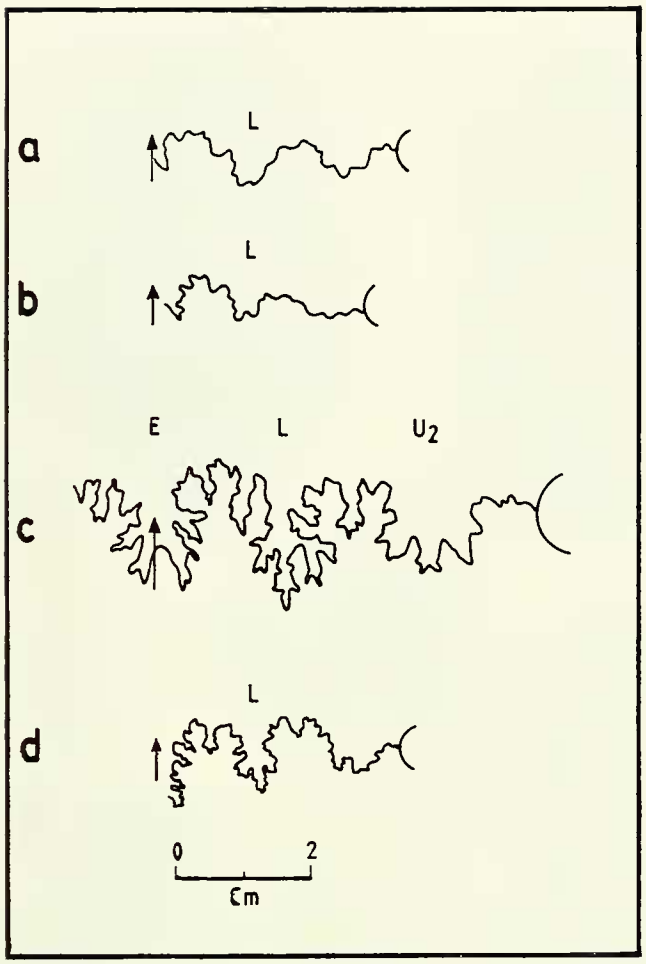


Figure 6. Septal sutures of *Kheraiceras*. **a, b.** Adult septal sutures of *Kheraiceras bullatum* (d'Orbigny) <M>, a: JUM/K/17 and b: JUM/K/9. **c.** Penultimate septal suture of the holotype (GSI type no. 2009) of *Kheraiceras cosmopolitum* (Parona and Bonarelli) <M>, after Spath 1928. **d.** Adult septal suture of *Kheraiceras* cf. *hannoveranum* (Roemer) <M>, JUM/J/10.

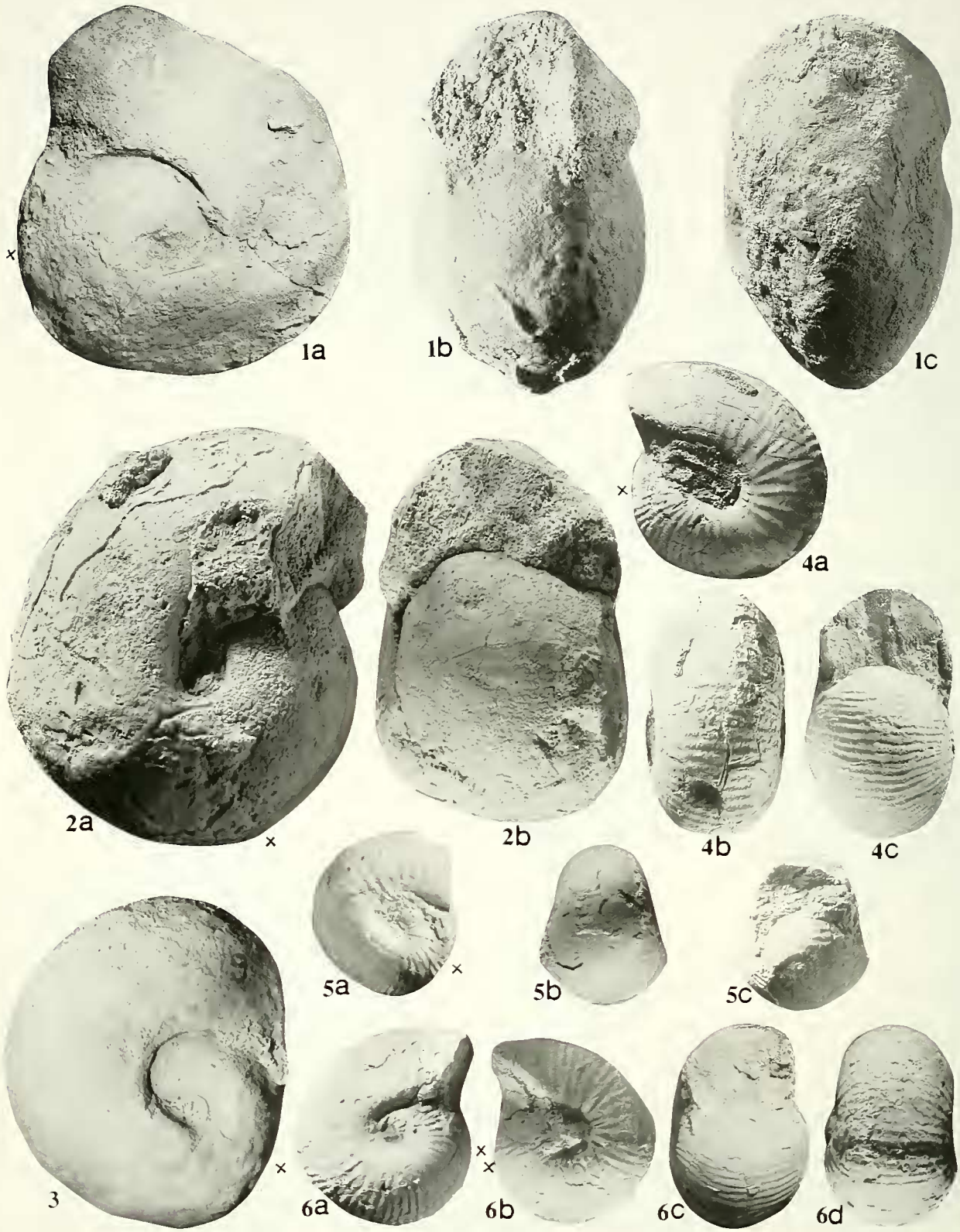
Table 1. Measurements for *Kheraiceras bullatum* (d'Orbigny, 1846) (in mm)

	Specimen		D	U	H	W
	Holotype	aperture	78	31	25	40
<M>	JUM/K/8	body chamber	61	20	24	33
			56(ca)	13	26	32
			52	8	28	38
<M>	JUM/K/9	body chamber	57	18	23	33
			54	17	24	32
		end-phragmocone	42(ca)	9	26	36
<M>	JUM/K/10	body chamber	59(ca)	13	21	22
			49	11	24	28
<M>	JUM/K/11	body chamber	57	20	22	23(ca)
		end-phragmocone	41	12	23	38(ca)
<M>	JUM/K/12	aperture	60	20	24	32
		end-phragmocone	40	12	22	40
<M>	JUM/K/13	aperture	47	14	18	27.5
		body chamber	43	10.5	19	26
			37	8	19	30
		end-phragmocone	34(ca)	8	14	23
<M>	JUM/K/17	aperture	67	20	29	38
		end-phragmocone	53(ca)	12	28	42
<m>	JUM/J/11	aperture	41	11	14	19
		body chamber	34	10	16	21
<m>	JUM/J/12	aperture	43	14	15	23
		body chamber	36	10	15	21
			34	9	16	21
<m>	JUM/J/13	aperture	35	12	16	20
		body chamber	30	7	13	19
			29	–	14	19
<m>	JUM/J/14	body chamber	28	8	11	17
			26	8	11.5	17
			23	5	11.5	19

Measurements.—To record the remarkable modification of the adult body chamber, multiple measurements at different positions are given for a few specimens (Table 1).

Description.—Macroconch<M>: Mostly internal mould, thin shell remains are rarely preserved. Body chamber ellipticonic, phragmocone spindle-shaped. Early whorls involute, relatively depressed (W/H=1.04–1.65), one inflated variant (JUM/K/12) having W/H=1.8. Maximum diameter observed is 67 mm, the specimen (JUM/K/17, Figure 7–2a,b) was still larger as evident from the trace of the last quarter of body chamber. Body chamber occupying almost whole of the last whorl. It partially occludes umbilicus at diameter 41 mm–55 mm immediately after end-phragmocone stage and shows a strong deviation from regular spiral, where it becomes straight initially and then egresses out ec-

⬅ **Figure 5.** Dimorphs of *Kheraiceras*. (All natural size). **1–4.** *Kheraiceras cosmopolitum* (Parona and Bonarelli). **1a, b.** Holotype <M> 2009, from Golden Oolite of Keera Bed 2, mostly internal mould, adult with incompletely preserved body chamber, highly depressed variant, lateral (a) and frontal (b) views. **2a–c.** Adult <M> with last quarter of body chamber missing, from Horizon V, Bed 5, Jumara, JUM/J/5, lateral (a), frontal (b) and ventral (c) views. **3a–c.** Almost complete <m>, from Horizon X, Bed 7, Jumara, JUM/J/6, lateral (a), frontal (b) and ventral (c) views. **4.** Adult <m>, body chamber fully preserved, but broken near venter, from Horizon IX, Bed 7, Jumara, JUM/J/2, note terminal constriction preserved at the flank, lateral view. **5a, b.** *Kheraiceras bullatum* (d'Orbigny), <M>, mostly internal mould with shell remains. Adult with almost completely preserved body chamber, from Horizon I, Bed 2, Keera, JUM/K/12, lateral (a) and frontal (b) views. ×: base of body chamber.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6c
6d

centrically, resulting in a wider umbilicus near peristome. Umbilicus varies ontogenetically (U/D=0.22–0.35), holotype being more evolute (U/D=0.40) relatively narrow, shallow to moderately deep in inner whorls; umbilical margin distinct and wall steeper throughout adult body chamber. Flanks short to slightly wide, flat to gently curved with rounded ventrolateral margin. Venter rounded, broad. Adult phragmocone diameter ranges from 40 to 53 mm and even less in a small variant, where the figure is about 34 mm. Maximum width of shell attained just at beginning of adult body chamber. Width of body chamber contracts maximally at middle part from where it gradually increases again. Whorl height on the other hand gradually decreases with increasing shell diameter. Aperture missing. Whorl depressed, semicircular to semielliptical in apertural outline.

Ribbing not well discernible as shell is mostly internal mould. Ribs appear to be dense and fine on inner whorls, while broad, distant and restricted on venter and seen at least up to diameter 57 mm in the adult body chamber. The number of secondaries on first half of outer whorl is about 24.

Both lobes and saddles not deeply incised. Both external and lateral lobes are frilled, but former are more slender. Incipient internal lobes less frilled. External saddle weakly bifid, first lateral saddle shallow, broad (Figure 6-a, b).

Microconch <m>: Mostly shell remains, strongly resembles macroconch in many morphological features (Figure 9) except being smaller in size (M : m≃1.42). Beginning of adult body chamber is marked by sudden egression of umbilical seam and maximum inflation (W/H=1.25 - 1.65) occurs just after it. Body chamber occupies nearly entire last whorl. Diameter of adult shell ranges from 35 to 43 mm. Apertural shape variable, elliptical to ovate. Peristome with slightly flared collar followed immediately by terminal constriction which cuts ribs obliquely. At middle part of body chamber of diameter 29 mm to 35 mm, apertural contraction is maximum, after which shell width again gradually increases towards aperture. Venter broad, strongly curved in inner whorls, becoming narrow and gently curved in body chamber. Laterals highly reduced, rounded up to end-phragmocone but widens and flattens later.

Both primary and secondary ribs are conspicuous, persistent up to peristome. Ribs fine and closely spaced in the early stage, becoming coarse and distant in outer whorl. Primaries rising from umbilical wall slightly rursiradiately, bifurcate irregularly at mid-flank or slightly higher. Secondaries and occasional solitaries go straight over venter. Number of secondaries in half whorl varies from 27 to 30.

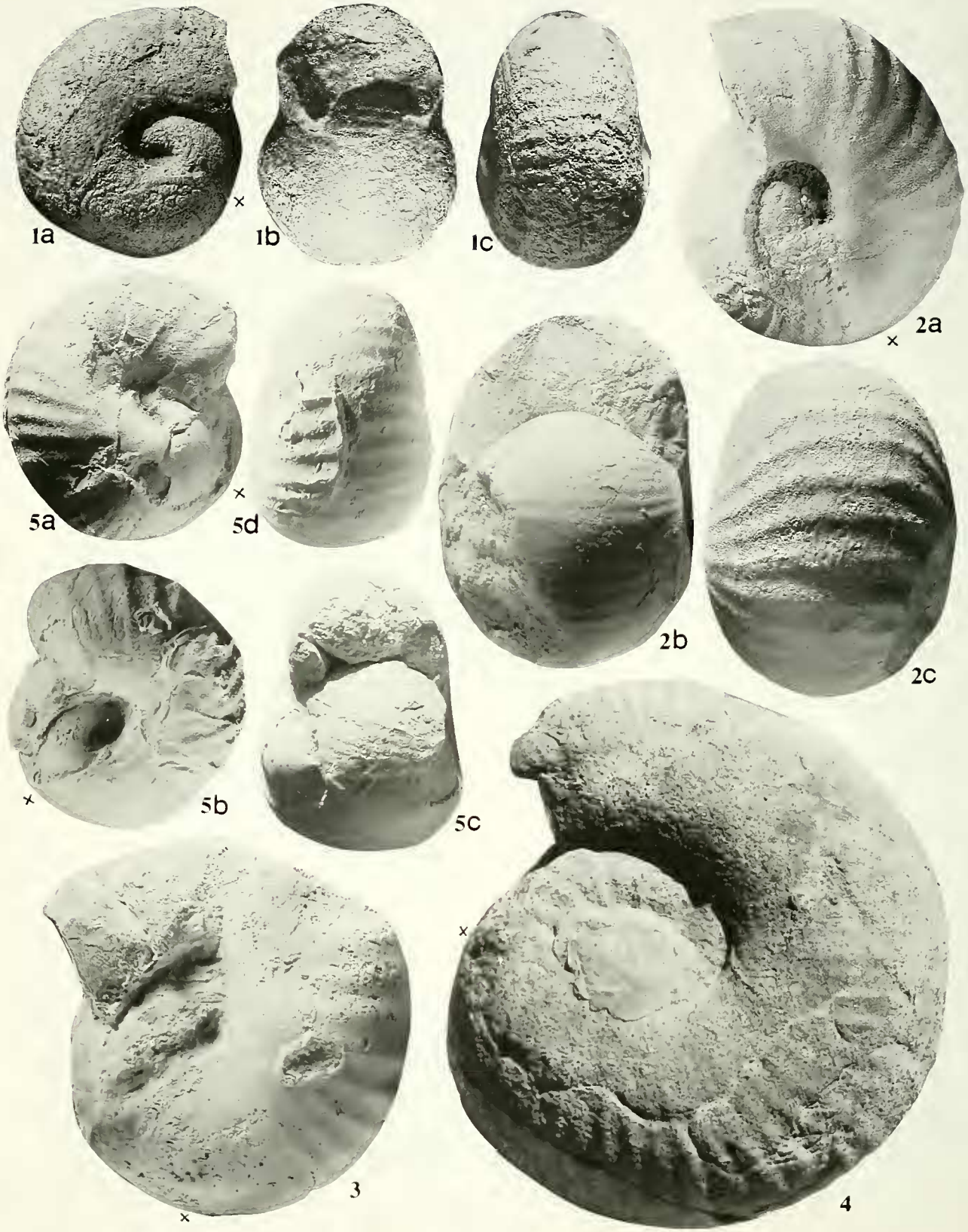
Septal suture not discernible.

Discussion.—Macroconchs of the present form are closely allied to the type specimens of *K. bullatum* (d'Orbigny, 1846) (see Arkell, 1954, text-fig. 34). They show strong resemblance in shell shape, whorl outline and nature of uncoiling of the umbilical seam. Ribbing pattern and the number of secondaries in the Kutch variant also agree more closely with the Lower Callovian *K. bullatum* s.s. The ribbing in the present macroconchs, however, is less conspicuous since most of them are internal moulds, and Arkell (1954) also pointed out that it is exaggerated in d'Orbigny's figure. However, d'Orbigny's species differs by its slightly larger adult shell diameter and relatively more inflated form. The stratigraphic and geographic distribution of *K. bullatum* is now better known. It is found in Europe, South America and Mexico, and ranges in age from Late Bathonian to Early Callovian (Cariou, 1984; Westermann *et al.*, 1984; Riccardi *et al.*, 1989; Sandoval *et al.*, 1990). The stratigraphic distribution of *K. bullatum* both in Kutch and France shows a phyletic size decrease (see also Krishna and Cariou, 1990). The relatively smaller adult size of the Kutch forms in comparison to those of Europe may, therefore, actually represent a smaller variant of a higher stratigraphic level or may be due to geographic variation (Bardhan *et al.*, 1999).

The microconch described here under the present species strongly resembles the macroconch of *K. bullatum* of both Kutch and European forms. Its phragmocone is similarly cadiconic but not much inflated like that of *K. cosmopolitum,* body whorl with typical *bullatum*-like uncoiling. The microconch, however, is characterised by much smaller adult size and apertural modification. In the microconch ribs are fine, dense, continuing all through the body whorl. Interestingly, in Kutch, although both dimorphs come from coeval stratigraphic horizons, they do not occur together. Macroconch specimens come from different stratigraphic levels within the Golden Oolite of Keera whereas the microconchs are found in different but coeval horizons of Jumara.

Microconch shows strong resemblance to different species of *Bomburites*. *B. devauxi* (de Grossouvre, 1891) (see Arkell, 1952, text-fig. 27), though similar in nature of shell shape and uncoiling, differs mainly by its smaller size, more depressed aperture and presence of strongly flared collar behind the terminal constriction. *B. globuliforme* (Gemmellaro, 1872) (see Arkell, 1952, text-fig. 27) has a shell size comparable to one of the variants of the present form (Figures 7-4a-c), but it is coarsely ornate and characterized by a peristome with a much flared collar. *K. prahecquense* of France also resembles the present form in shell diameter and *K. bullatum*-like other features. In Kutch both dimorphs are found at the same stratigraphic levels, but *K. prahecquense* appears only after the disappearance of *K.*

← **Figure 7.** *Kheraiceras bullatum* (d'Orbigny). (All natural size). **1a-c.** Adult <M>, internal mould, body chamber fully preserved, from Horizon I, Bed 2, Keera, JUM/K/8, lateral (a) frontal (b) and ventral (c) views. **2a, b.** Adult <M>, internal mould, almost completely preserved body chamber, from Horizon I, Bed 2, Keera, JUM/K/17, lateral (a) and frontal (b) views. **3.** Almost completely adult <M>, internal mould, aperture missing, from Horizon I, Bed 2, Keera, JUM/K/9, lateral view. **4a-c.** Adult <m>, with terminal constriction preserved near the flank, from Horizon VII, Bed 6, Jumara, JUM/J/12, lateral (a), ventral (b) and frontal (c) views. **5a-c.** Almost completely adult <m>, with partially preserved body chamber, from Horizon VI, Bed 5, Jumara, JUM/J/14, lateral (a), ventral (b) and frontal (c) views. **6a-d.** Complete adult specimen <m>, from Horizon VII, Bed 6, Jumara, JUM/J/13, lateral (a,b), frontal (c) and ventral (d) views. Note terminal constriction in 6b. ×: base of body chamber.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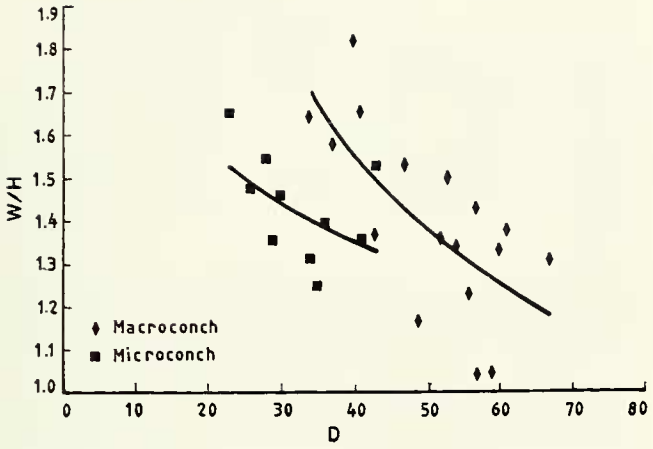


Figure 9. Best-fit growth curves of whorl section of macroconch and microconch of *Kheraiceras bullatum* (d'Orbigny).

bullatum, thus making two distinct subzones (Cariou, 1984). Recently, *Ammonites microstoma* d'Orbigny (see Arkell, 1954, text-fig. 35) has been considered as a possible microconch of *K. bullatum* (Westermann and Riccardi, 1979 and Westermann and Callomon, 1988). *A. microstoma, though,* with a less depressed phragmocone, has a gradual *Bullatimorphites*-like uncoiling of the body chamber. It appears that the present microconchiate forms are the better candidates to match to the true, i. e., macrochonchiate form of *K. bullatum*.

The present macroconch closely resembles *K.* cf. *hannoveranum* <M>, described here, but the latter is larger and strongly ornate. Detailed comparison, however, is given in the discussion part of *K.* cf. *hannoveranum*.

Noetling's (1896) *'Sphaeroceras'* cf. *bullatum* is a giant *Kheraiceras* and considered as *K.* cf. *bullatum* by Pandey and Westermann (1988) and Westermann and Callomon (1988). Arkell (1954) also compared it with the European *K. bullatum* s.s. Noetling described the species from the Upper Bathonian Polyphemus Limestone, Baluchistan. We have inspected the only monotypic specimen reposited in the Geological Survey of India, Calcutta (Type No. 2915). Admittedly it is comparable with the European *K. bullatum* in coiling and ribbing pattern, but it is exceptionally large for the genus, having a diameter of 158 mm. Its body whorl is highly contracted and the aperture is barely in contact with the ventral surface of the preceding whorl. Besides, the phragmocone does not become depressed as much as in *K. bullatum* and ribs disappear much earlier in the inner flank on the body chamber. The Baluchistan specimen is described here as a new species, *K. noetlingi* sp. nov.

K. cosmopolitum (Parona and Bonarelli, 1895), the type species, comes also from Kutch and stratigraphically overlaps the present species in the lower part of its range. This species and *K. bullatum* are closely related and their microconchs are also known. The nature of dimorphism is quite distinct and speaks for their specific separation. Both morphs of *K. cosmopolitum* have much inflated phragmocone, more depressed aperture and more eccentrically coiled body chamber than those of the present species. Microconchs of the two species are ornate to the end and characterised by apertural modification, but the microconch of *K. bullatum* has relatively fine, denser ribbing and more secondaries in the outer whorl than in *K. cosmopolitum*. Septal sutures are well discernible in macroconchs only, which are mainly represented by internal moulds. *K. cosmopolitum* has a more complex sutural pattern (Figure 6–c) at the same growth stage. Interestingly, both the species differ in macroconch-microconch size ratio which is greater in *K. cosmopolitum* (M : m≈2.05).

Kheraiceras spathi sp. nov. <m> described later, is readily distinguishable from the microconch of the present species by its elliptically coiled body chamber, less depressed and less evolute early whorls, and pronounced terminal constriction.

Microconch of the present species differs from *Kheraiceras* sp. A <m>, described later, in being larger with coarse ornamentation and widely spaced ribbing.

Westermann *et al.* (1984) described *B. (K.) bullatum* from Mexico based on a full-grown and almost complete specimen (pl. 2, fig. 8a–b). Its obsolete ribbing on the body chamber and number of secondaries agree closely with some of our specimens of the present species. However, this Mexican form is slightly larger and may be an older geographic variant since it comes from the Upper Bathonian horizon. *Bullatimorphites (Kheraiceras) v-costatus* from the Upper Bathonian of Caracoles, Chile is a large and coarsely ornate form (Riccardi *et al.*, 1989, pl. 8, figs. 3, 4). This form is even larger than true *K. bullatum* <M> (d'Orbigny, 1846) of Europe and the Kutch form. Its ribbing is strong, distant and seems to persist on most of the outer whorl, and thus perhaps agrees closely with contemporary *K. hannoveranum* (Roemer).

Recently Géczy and Galacz (1998) described a new Late Bathonian species *Bullatimorphites* (*Bullatimorphites*) *dietli* from South Hungary. The paratype of the species (Géczy

← **Figure 8.** *Dimorphs of Kheraiceras.* (All natural size). **1a–c.** *Kheraiceras bullatum* (d'Orbigny) <M>, internal mould, small variant, complete adult specimen, from Horizon II, Bed 2, Keera, JUM/K/13, lateral (a), frontal (b) and ventral (c) views, note obsolete ribbing restricted on the venter. **2–5.** *Kheraiceras* cf. *hannoveranum* (Roemer) <M> and <m>. **2a–c.** Adult <M> with last 1/3 of the body chamber missing, from Horizon IV, Bed 4, Jumara, JUM P-2, lateral (a), frontal (b) and ventral (c) views. **3.** Adult <M>, one half is damaged, last part of the body chamber crushed, from Horizon V, Bed 5, Jumara, JUM/J/10, lateral view. **4.** Almost complete adult specimen <M>, one side damaged, from the Polyphemus Limestone, Mazardrik, Baluchistan, kept in Indian Museum, Calcutta, type no. H. 48.607, lateral view. **5a–d.** Almost complete adult specimen <m>, peristome missing, from Horizon I, Bed 2, Keera, JUM/K/7, lateral (a,b), frontal (c) and ventral (d) views. Note retention of coarse, distant ribbing to the end. ×: base of body chamber

and Galacz, 1988, pl. III, fig. 7) resembles our smaller, younger variant (Figure 8.1a-c) from the late Early Callovian in nature of umbilical uncoiling and adult body whorl length.

Sandoval *et al.* (1990) recently established dimorphism in *K. bullatum* from the Upper Bathonian of Mexico. They synonymised their microconch with *Bomburites microstoma*, but the Mexican form differs from that of d'Orbigny. It, in fact, is very closer to the present microconch and one Mexican variant (*ibid.* pl. 9, 3a-c) is barely distinguishable.

Occurrence. — *Kheraiceras bullatum* has a wide biogeographic distribution. Besides Kutch, it occurs in Europe, South America and Mexico from the Late Bathonian to Early Callovian. In Europe the species is abundant in France. The lectotype (see Arkell, 1954, text-fig. 34) comes from the Upper Bathonian. The species is common in the Bullatum Subzone of the Lower Callovian (Cariou, 1984). *K.* cf. *bullatum* is reported from the East Pacific faunal province. In Mexico it appears in the lower part of the Steinmanni Zone (=upper part of Restrocostatum Zone or Aspidoides Zone of Europe), and is associated with *Epistrenoceras histricoides,* indicating a Late Bathonian age (Westermann *et al.,* 1984; Sandoval *et al.,* 1990). In Argentina it comes from the Vergarensis Zone, which is equivalent to the Macrocephalus Zone of Submediterranean France (Riccardi *et al.,* 1989).

All seven macroconchs from Kutch localities come from different horizons within Bed 2, Keera. JUM/K/8 - 12, JUM/K/17 from Horizon I and JUM/K/13 from Horizon II. Four microconchs come from Jumara. JUM/J/14 from Horizon VI, Bed 5; JUM/J/12-13 from Horizon VII, Bed 6 and JUM/J/11 from Horizon IX, Bed 7.

Kheraiceras cf. ***hannoveranum*** (Roemer)

Figures 6d; 8.2-8.5

Macroconch.—

1911 *Sphaeroceras quenstedti* var. *hannoverana* n.v. Roemer, p. 42, pl. 7, figs. 16, 21, pl. 8, fig. 1.
1915 *Sphaeroceras bullatum* d'Orbigny. Lóczy, p. 351, text-fig. 79.
1925 *Kheraiceras ? stansfieldi* Spath, pl. I, fig. 2a-b.
1952 *Bullatimorphites hannoveranus* (Roemer). Arkell, p. 108.
1958 *Bullatimorphites bullatus hannoveranus* (Roemer). Westermann, p. 65, pl. 21, figs. a-b.
1970 *Bullatimorphites* (*Bullatimorphites*) *cf. hannoveranus* (Roemer). Mangold, p. 303, figs. 96-97.
1971 *Bullatimorphites cf. hannoveranus* (Roemer). Hahn, pl. 7, fig. 3.
1988 *Bullatimorphites* sp. Bardhan, Datta, Khan and Bhaumik, pl. 1, fig. 1a-*c*.
1993 *Kheraiceras* sp. nov. A. Callomon, p. 235.
1994 *Bullatimorphites* (*Kheraiceras*) *hannoveranus* (Roemer). Dietl, p. 10, pl. 1, fig. 2.
1997 *Bullatimorphites* (*Kheraiceras*) *hannoveranus* (Roemer). Mangold and Rioult, pl. 18, fig. 6.
1998 *Bullatimorphites (Bullatimorphites) hannoveranus* (Roemer). Géczy and Galacz, pl. III, figs. 1a-b, 2a-b, text-fig. 9.

Macroconch and microconch.—

1999 *Kheraiceras* cf. *hannoveranum* (Roemer). Bardhan, Sardar and Jana, pl. 1, figs. 7-9.

Material. — The present collection includes three macroconchs and one microconch. Two macroconchs (JUM P-2, JUM/J/10) are collected from Beds 4 and 5 of Jumara (Horizons IV and V in Figure 2), Kutch, and the other one is from the Polyphemus Limestone, Mazardrik, Baluchistan, and now kept in the Indian Museum (H 48.607), Calcutta. The only microconch, JUM/K/7 comes from the lower part of the Golden Oolite (Bed 2, Horizon I in Figure 2) of Keera.

Measurements.—See Table 2.

Description.—Macroconch <M>: Shell elliptoconic, moderately inflated, involute up to adult phragmocone stage and then becomes evolute with rapid uncoiling of umbilical seam. Whorl section depressed, ovate. Adult phragmocone diameter ranges from 45 to 60 mm. Adult body chamber covering more than 3/4 of the last whorl. Maximum shell diameter observed is about 100 mm. Maximum inflation (W/H=1.27-1.76) occurs at or just after end-phragmocone; both width and height show negative allometry afterwards.

Umbilicus shallow and umbilical margin is steep up to end-phragmocone diameter or early part of body chamber but later gradually becoming less inclined. Sudden egression of umbilical seam coincides with beginning of body chamber; first it goes straight up to about 18 mm length occluding partially umbilicus of inner whorl, then turns inwards eccentrically towards aperture resulting in a 'hook-shaped' body chamber. Flank short, barely existing in inner whorl but with ontogeny becomes broad and gently curved. Venter broad, highly curved at early stage but becomes gently rounded on adult body chamber. Ventrolateral margin is always rounded.

Shell coarsely ornate on body chamber. Phragmocone with relatively fine and dense secondaries; primaries short, regular and bifurcating on inner flank, and originating from umbilical margin. They disappear, resulting in smoothening of inner flank of body chamber while secondaries suddenly become coarse, distant and traced up to end of body chamber. Secondaries assume a broad, convex pattern aborally and then flex forward near ventrolateral margin and go over venter with slight forward projection. Number of secondaries on first half of outer whorl is 24.

Both external and lateral saddles are large, frilled.

Table 2. Measurements for *Kheraiceras* cf. *hannoveranum* (Roemer) (in mm).

Specimen		D	U	H	W
<M> JUM/J/10	body chamber	72(*ca*)	19	27	38
		61	20	34	44
	end-phragmocone	51	–	26	40
<M> JUM P-2	body chamber	60	14	24	40
		49	7	25	44
	end-phragmocone	45	7	24	40
<M> H 48.607	aperture	99(*ca*)	33	27(*ca*)	–
	end-phragmocone	60(ca)	–	24	34
<m> JUM/K/7	aperture	48	12	17	27
	body chamber	42	13	22	28
		35(*ca*)	5	23	33

External saddle bifid with deeply incised secondary lobes, lateral lobe deep, narrow (Figure 6-d).

Microconch <m>: It replicates macroconch in all major aspects barring size. Body chamber occupies almost whole of last whorl. Maximum diameter observed is 48 mm. Maximum inflation (W/H≈1.59) occurs on adult body chamber at diameter 35 mm followed by sudden contraction with decrease of both height and width. Aperture missing. Body chamber, initially after deviating from the regular spiral, goes straight for a distance of about 12 mm and then turns centrifugally towards the aperture.

Ornamentation similar to that on macroconch but both primaries and secondaries retained without losing strength up to end of preserved body chamber. Number of secondaries on first half of outer whorl is about 30.

Discussion.—The present species can be readily distinguished from other Kutch forms by its coarsely ornate ribbing which persists to the end of adult conch, sutural pattern and nature of dimorphism. However, it occupies morphometrically an intermediate position between highly depressed *K. cosmopolitum* and relatively compressed *K. bullatum* (see Figure 10).

The present species differs from *K. cosmopolitum* by its less contracted body chamber and less inflated phragmocone, relatively simple sutural pattern and more distant, coarse ribbing persistent up to the end of the body chamber. Moreover, in *K. cosmopolitum*, the growth of shell width relative to shell diameter shows negative allometry, while in the present species both width and height of the body chamber decrease with increasing shell diameter. Flanks are wider than in *K. cosmopolitum*. Moreover, dimorphic size ratio between these two species also differs.

The lectotype of *K. hannoveranum* from the Upper Bathonian Orbis Zone of Germany matches well with the macroconchs of the present species in having a less inflated phragmocone and coarse ribbing which persists to the end. Jain *et al.* (1996) also compared one of the variants (JUM P-2, Figures 8-2a-c) of the present Kutch form with *Bullatimorphites* cf. *hannoveranus* (Roemer, 1911, pl. 8, fig. 1 ; Hahn, 1971, pl. 7, fig. 3) and *B.* (*Bullatimorphites*) cf. *hannoveranus* (Mangold, 1970, p. 303, figs. 96-97) from the Upper Bathonian Restrocostatum Zone of the Southern Jura. Callomon (1993) also noticed a similarity between the same Kutch specimen (JUM P-2) and *B. costatus* Arkell (Lissajous, 1923, p. 18, fig. 2), and *K. suivecum* (Roemer) (pl. 7, fig. 21). The latter species has now been regarded as a microconch of the present species (Géczy and Galacz, 1998) and the type specimens of *K. suivecum* (see Arkell, 1952, text-fig. 36) are quite comparable with the microconch of the present speceies (JUM/K/7) described herein (Figure 8-5a-d). All of them are characterised in having strongly ornate outer whorl and ribbing which continues to the end without losing strength.

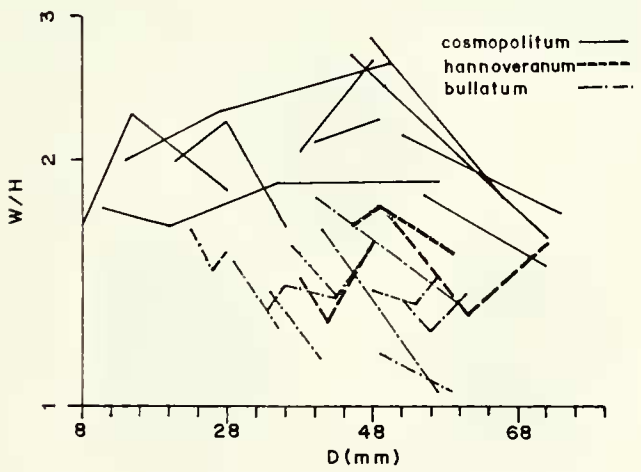


Figure 10. Growth curve of whorl section of both macroconch and microconch of three species of *Kheraiceras* in Kutch. Continuous line graph shows developmental change in a specimen.

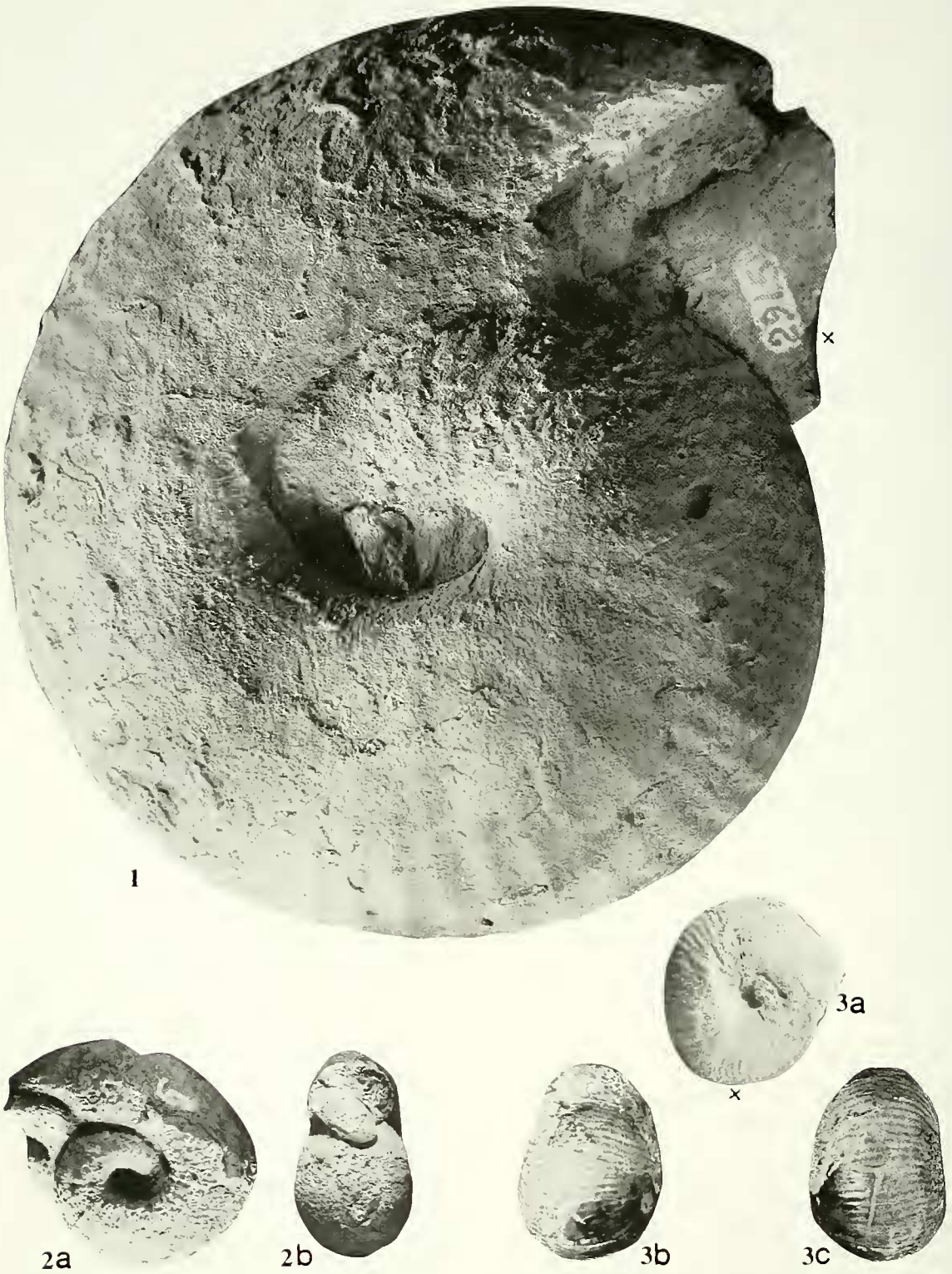
The European macroconchs of the present species are larger in size and come from the older stratigraphic horizons. The present forms come from beds ranging in age from Late Bathonian to earliest Callovian. It appears that their smaller adult size may be due to geographic variation as well as younger straitigraphic age, since phyletic size decrease is found in many species of *Kheraiceras*.

The macroconch of the present species is a close ally of that of *K. bullatum*, but differs in relatively large adult size and less contracted and less aberrantly coiled body chamber. Besides, in *K. bullatum* ribs are finer, more numerous, restricted mainly on the venter, and disappear finally near the aperture, while coarse, distant ribs which persist throughout the last whorl characterise the present species. Remarkably, these differences are also observed in microconchs.

Kheraiceras? *stansfieldi* described by Spath (1925, pl. I, fig. 2a-b) from the 'Lower Callovian' Macrocephalus Zone of Madagascar, which is represented by an adult steinkern with crowded septal sutures and an incomplete body chamber, matches well with one of our specimens (Figures 8-2a-c) coming from the Madagascariensis Horizon. Both Kutch and Madagascan forms are similarly less depressed in apertural outline and have a rounded umbilical margin, and prorsiradiate ribs. Interestingly, the Madagascan form comes from the same locality and horizon which yield *Macrocephalites madagascariensis*. We believe that *Kheraiceras*? *stansfieldi* and the present *K.* cf. *hannoveranum* are conspecific.

Occurrence.—The lectotype of *K. hannoveranum* comes from the Upper Bathonian Orbis Zone of Germany. It closely resembles the Kutch form. The other Upper Bathonian specimens of the present species e.g., *Bullatimorphites* cf. *hannoveranus* (Roemer, 1911, pl. 8, fig. 1; Hahn, 1971, pl. 7, fig. 3), and *B.* (*Bullatimorphites*) cf. *hannoveranus* (Mangold, 1970, figs. 96-97, cited in Jain *et al.*, 1996) come from the Upper Bathonian Restrocostatum Zone of the Southern Jura.

Among our three macroconchs, JUM P-2 comes from Horizon IV, Bed 4, Jumara and JUM /J/10 from Horizon V, Bed 5, Jumara. The other one (H 48.607) comes from the Polyphemus Limestone, Mazardrik, Baluchistan. The only microconch (JUM/K/7) comes from Horizon I, Bed 2, Kerra.


1
2a
2b
3a
3b
3c

Kheraiceras spathi sp. nov.

Figures 11.2a, b

Microconch.—

1931 *Kheraiceras* aff. *cosmopolita*, Spath, pl. XCVI, fig. 8a–b.

1999 *Kheraiceras* sp. B. Bardhan, Sardar and Jana, pl. 1, fig. 12.

Material.—The present species is represented only by the holotype specimen (JUM/J/15) collected from Horizon V, Bed 5 of Jumara.

Diagnosis. — Shell small, compressed; inner whorls evolute, umbilical wall overhanging, depressed phragmocone, much contracted body chamber; width decreases during ontogeny, while height remains constant on outer whorl; retaining ancestral *Bullatimorphites*-like gradual uncoiling of body chamber, but characterised by flared peristome and highly contracted body chamber.

Etymology.—In honour of L.F. Spath, England, who first studied this species.

Measurements.—See Table 3.

Description.—Microconch <m>: Mostly internal mould, small, slender in shape (W/D=0.84 to 0.41, during ontogeny of outer whorl). Inner whorl sphaeroconic, gradually uncoiled to ellipticonic outer whorl. Body chamber occupies almost whole of last whorl. Maximum diameter observed is 36 mm. Beginning of body chamber at about 22 mm, marked by slightly inward curving of outer whorl, thus occludes partially inner umbilicus (U/D=0.21) and followed thereafter by gradual eccentric coiling, so that at aperture body chamber is in contact only with ventral surface of preceding whorl (U/D=0.33). Inner whorl relatively evolute, depressed with laterals barely existing. Venter broad, strongly curved. Umbilical margin sharp, angular with overhanging umbilical wall. Inner flanks gradually flatten and umbilical margin becomes rounded near aperture. Maximum inflation (W/H≈1.9) of shell is attained after beginning of adult body chamber. Width decreases from the early part of adult body chamber with increase of shell size, but height remains almost unchanged. Laterals widen and venter narrows ontogenetically on body chamber; whorl section depressed, ovate (at aperture, W/H=1.5). Aperture with deep, broad terminal constriction which rises very sharply in rursiradiate manner near inner margin, then proceeds with a broad forward projection towards outer margin. Peristome projected forward at venter. Aperture immediately next to the constriction appears to be slightly flared in internal mould.

Ribbing fine, feeble on internal mould but appears to be persistent up to aperture. Suture not well discernible.

Discussion.—The microconchiate affinity of the present specimen is obvious in its smaller size and contracted adult body chamber with modifications at the peristome.

The present species strongly recalls '*Bomburites*', a genus which is now considered as microconchs of *Kheraiceras*. It is a close match of the holotype of the type species *Bomburites devauxi* (de Grossouvre, 1891) (Arkell, 1954, text-fig. 27). However, the present species differs mainly by its gradual uncoiling of the body chamber, fine ribbing, relatively larger adult size and absence of any prominent flared collar at peristome.

Spath's (1931) *Kheraiceras* aff. *cosmopolita* (pl. XCVI, figs. 8a–b) which comes from the same stratigraphic horizon (Bed 5) and same locality at Jumara, resembles so strikingly the present species that they appear to be conspecific.

The present species differs from microconchs of all other *Kheraiceras* spp. of Kutch by its compressed form, gradual uncoiling of umbilical seam and inwardly sloping umbilical wall. It differs from *K. bullatum* <m> by its gradual uncoiling of umbilical seam, elliptoconic body chamber and less ornate shell.

K. cosmopolitum <m> is the most tumid species (W/D= 0.69–1.03) of the present group, with an eccentrically coiled body chamber. It has a more depressed phragmocone and aperture than those of *K. spathi*. Besides, ribs in *K. cosmopolitum* are coarser and more distant.

Microconch of *K.* cf. *hannoveranum* is readily distinguishable from the present form in having larger shell diameter, strong ornamentation, highly contracted and aberrantly uncoiled body chamber.

The original figure of *Ammonites microstoma* described by d'Orbigny (1846, pl. 142, figs. 3–4) which was refigured by Arkell (1954, text-fig. 35) is closely comparable with the present form, particularly with respect to gradual uncoiling of the body chamber and presence of a deep terminal constriction. *A. microstoma* d'Orbigny, 1846 is now considered as a microconch of *Kheraiceras*. It, however, differs from the present form in its larger size, strongly ornate shell and distinct collar.

Spath (1931) compared the present form with *K. globuliformi* (Gemmellaro, 1872) (Parona and Bonarelli, 1895, pl. VI, fig. 1) but the latter species is larger in size and characterized by coarse ribbing, more eccentrically coiled body chamber and highly flared peristome.

Occurrence.—The monotypic holotype (JUM/J/15) comes from a horizon (HorizonV, Bed 5, Jumara) which lies just

Table 3. Measurements for *Kheraiceras spathi* sp. nov. (in mm).

	Specimen		D	U	H	W
<m>	Holotype, JUM/J/15	aperture	36	12	10	15
		body chamber	29	8	10	17
		near end-phragmocone	23	5	10	19.5

← **Figure 11.** Dimorphs in *Kheraiceras*. (All natural size). **1.** *Kheraiceras noetlingi* sp. nov. <M>, holotype, (type no. 2915), complete adult, from the Polyphemus Limestone, Mazardrik, Baluchistan, now kept in Curatorial Division, Geological Survey of India, Calcutta, lateral view. **2a, b.** *Kheraiceras spathi* sp. nov. <m>, holotype, internal mould, complete adult specimen with deep terminal constriction from Horizon V, Bed 5, Jumara, JUM/J/15, lateral (a) and frontal (b) views. **3a–c.** *Kheraiceras* sp. A. <m>, adult with almost completely preserved body chamber, abraded near the last part, from Horizon III, Bed 2, Keera, JUM/K/16, lateral (a), frontal (b) and ventral (c) views ; note fine, dense ribbing. x: base of body chamber.

above the Bathonian-Callovian boundary.

Kheraiceras sp. A

Figures 11.3a–c

Microconch.—

1999 *Kheraiceras* sp. A. Bardhan, Sardar and Jana, pl. 1, fig. 11.

Material.—Only one specimen (JUM/K/16) collected from the Golden Oolite (Bed 2, Horizon III in Figure 2), Keera.

Measurements.—See Table 4.

Description.—Microconch <m>: Shell small, elliptoconic? (W/D≈0.46); strongly involute inner whorls. Adult phragmocone at about 21 mm. Maximum inflation (W/H=1.8) is attained after beginning of body chamber at 26 mm. Width of body whorl decreases rapidly with ontogeny while height

Table 4. Measuremetns for *Kheraiceras* sp. A (in mm).

Specimen		D	U	H	W
<m> JUM/K/16	aperture	?30	7(ca)	11.5	14
	body chamber	31	7(ca)	12	19
		26	4.5	11	20

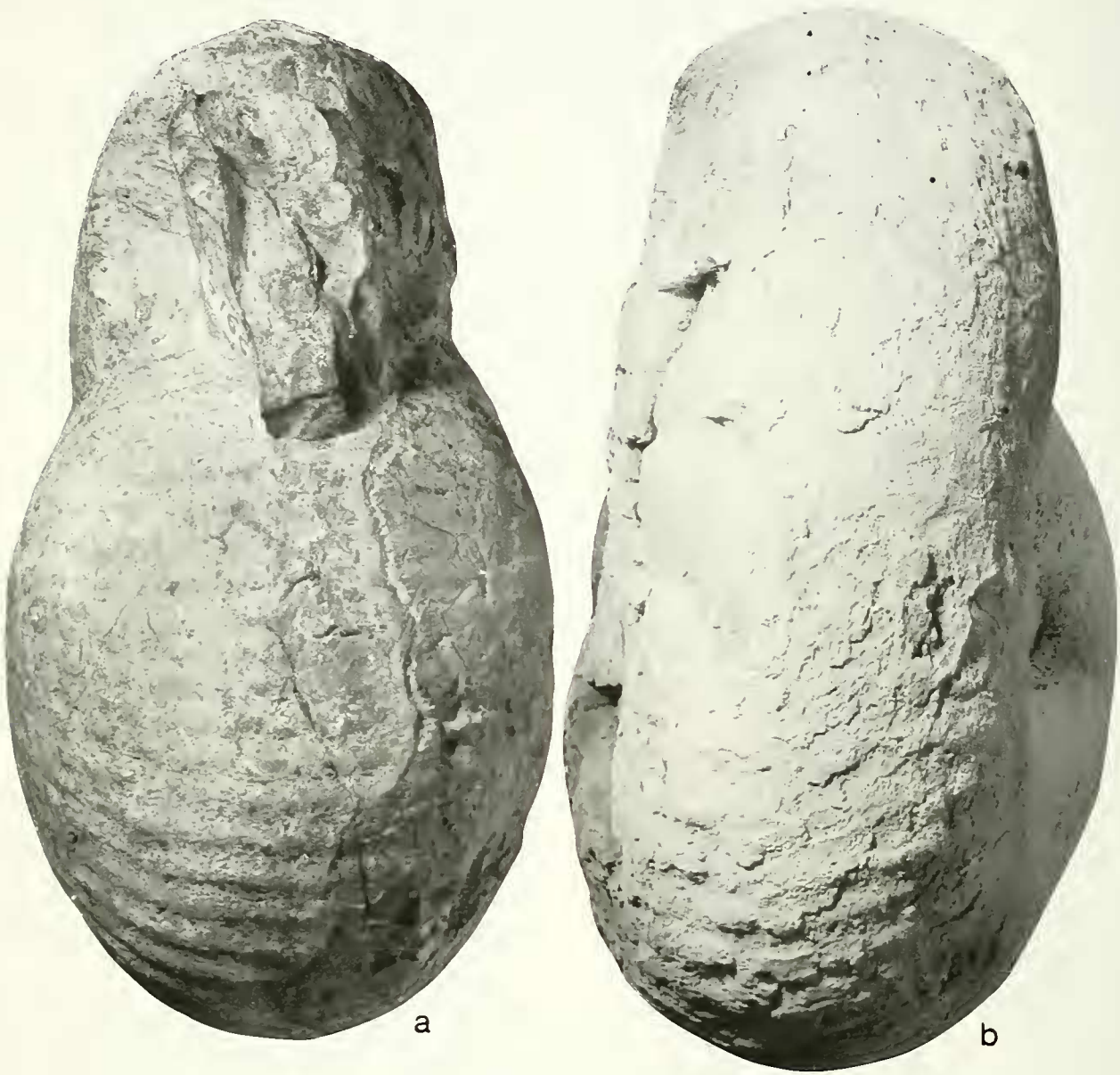


Figure 12. *Kheraiceras noetlingi* sp. nov. <M>, same as figure 11.1, frontal (a) and ventral (b) views. (All natural size).

remains more or less same. Body chamber occupies more than 3/4 of last whorl, largest shell diameter being 31 mm, which occurs near middle part of body chamber. Afterwards shell diameter decreases slightly which may be due to secondary crushing of specimen. Aperture missing. Initially, umbilical seam deviates from regular spiral and goes straight in direction of largest shell diameter; then it suddenly turns inward and barely touches ventral surface of penultimate whorl. Venter broad, rounded and narrows down gradually towards aperture. Flanks short, less curved near mature phragmocone; both ventrolateral and umbilical margins gradual.

Ribs fine, dense, persisting till end. Primaries originating from umbilicus, straight to slightly rursiradiate near inner margin, and furcate irregularly either at or sligtly above midflank. Secondaries feebly sinuous or straight across venter, about 34 on first half of outer whorl.

Septal suture not discernible.

Discussion.—The present species differs from *K. cosmopolitum* <m> by its smaller size, less depressed early whorls and more fine and dense ribbing.

It is smaller than *K. bullatum* <m> and body chamber is more contracted and aberrantly uncoiled. Besides, they differ in ribbing pattern and number of ribs per half whorl.

The described specimen also strongly recalls the holotype of '*Bullatimorphites*' *uhligi* (Popovichi-Hatzeg, 1905, pl. 6, fig. 7) (see Arkell, 1954, text-fig. 36). They both are characterised by fine dense ribbing and strongly involute phragmocone and may be conspecific if enough material is available. Unfortunately, the holotype of '*B.*' *uhligi* has an incomplete body chamber.

The unique holotype of *K. spathi* sp. nov. has a comparable adult shell diameter and fine, dense ribbing. It has, on the other hand, characteristic *Bullatimorphites*-like gradual uncoilding of body chamber and compressed shell shape. Besides, the present form differs also by its strongly involute inner whorls and less contracted aperture.

Occurrence.—Single speciment (JUM/K/16) from Horizon III of Bed 2, Keera.

Kheraiceras noetlingi sp. nov.

Figures 11.1 ; 12a, b

Macroconch.—

1896 *'Sphaeroceras'* cf. *bullatum* d'Orbigny, Noetling, pl. 6, fig. 2, 2a.

1933 *Kheraiceras quenstedti* (J. Roemer). Spath, p. 808.

1999 *Sphaeroceras bullatum* Bardhan, Sardar and Jana, pl. 1, fig. 10.

Material.—The holotype, a unique specimen described by Noetling (1896, pl. 6, fig. 2, 2a) from the Polyphemus Limestone, Mazar Drik, now reposited in GSI (Type No. 2915) and refigured here (Figures 11.1; 12a, b).

Diagnosis.—Unusually large for the genus; less cadiconic phragmocone, aperture highly contracted, inner whorls involute, body chamber eccentrically uncoiled and barely in contact with the ventral surface of the preceding whorl, apertural whorl section elliptical; ribbing coarse, distant, becoming obsolete in the first half of the body chamber.

Table 5. Measurements for *Kheraiceras noetlingi* sp. nov. (in mm).

	Specimen		D	U	H	W
<M>	Holotype,	aperture	158	49	55	60
	GSI Type	body chamber	132	34	51	60
	No.2915	end-phragmocone	127	17	50	90

Etymology.—In honour of F. Noetling, who first studied this species.

Measurements.—See Table 5.

Description.—Macroconch <M>: Internal mould, large, relatively compressed (W/D≈0.7). Complete adult specimen with maximum diameter 158 mm. Shell involute in early whorls, but becoming evolute in last whorl. Umbilical seam turns inward occuluding partially umbilicus of inner whorls, end-phragmocone diameter 103 mm. Thereafter adult body chamber, which occupies more than 3/4 of last whorl, coils eccentrically and becomes very narrow at aperture, resulting in a wide umbilicus. Maximum inflation attained at end-phragmocone stage (W/H=1.8) followed by rapid contraction of body chamber which is maximum at about diameter 132 mm (W/H=1.17), thereafter height increases relative to width and at aperture W/H=1.09. In inner whorls, umbilical wall steep with umbilical margin relatively sharp to rounded but gradually becomes inclined with rounded umbilical margin on outer whorl. Flanks short and rounded in inner whorls, increase and tend to become less curved ontogenetically. Venter relatively broad and gently rounded up to end phragmocone, narrowing and arching strongly during later ontogeny. Apertural whorl section strongly depressed, ovate near beginning of body chamber and at aperture relatively compressed and elliptical.

Primary ribs prominent up to end phragmocone stage. They originate from umbilical wall slightly rursiradiately and furcate below midflank. Secondaries strong and distant, become gradually indistinct and restricted near venter and persist up to 3/4 of last whorl. Number of secondaries in first half whorl is about 30.

Discussion.—As far as we know the present species represents the largest *Kheraiceras* in the world. From its size alone it matches many *Bullatimorphites* species. *Bullatimorphites* and *Kheraiceras* form an evolving lineage and there exist several species which show morphologic overlapping (Sandoval, 1983; Pandey and Westermann, 1988). The affinity of the present species towards *Kheraiceras* is nevertheless unequivocal, based on its inflated phragmocone, eccentric coiling of umbilical seam and rapidly contracted body chamber. Although it comes from the Upper Bathonian sequence of Baluchistan (Noetling, 1896; Arkell, 1956), it is known that both *Bullatimorphites* and *Kheraiceras* overlap stratigraphically in the Upper Bathonian. *Bullatimorphites* has a very restricted geographic distribution and comes mainly from the Mediterranean Province.

Both Noetling (1896) and Arkell (1952) found the present holotype conspecific with the European *Kheraiceras bullatum* (d'Orbigny, 1846). Admittedly, the present species

resembles *K. bullatum* which ranges from the Late Bathonian to the earliest Callovian (Riccardi *et al.*, 1989), but the adult size difference between them is remarkable. Besides, d'Orbigny's type specimen of *K. bullatum* (see Arkell, 1952, text - fig. 34) has a more eccentrically coiled and less contracted adult body chamber and more depressed phragmocone. The present species also differs from the Indian form of *K. bullatum* <M>, described here, mainly by its adult size and coarser and distant ribbing.

Bullatimorphites cf. *hannoveranus* (Roemer, 1911) <M>, now known from both Europe and India, is also a larger form with coarser ornament and strongly recalls the present species. The present species, however, differs in having cadiconic, spindle-shaped inner whorls, highly contracted body chamber and less strong ribbing on the body whorl which becomes indistinct in the first half of body chamber and disappears thereafter. Study of *K.* cf. *hannoveranum* <M> reported here, makes the difference more apparent. Its body chamber is strongly ribbed and ribbing persists to the end without losing strength.

Occurrence. —The holotype comes from the Polyphemus Limestone bed, Mazardrik, Baluchistan. Judging from the faunal association which includes *Macrocephalites triangularis* 'group', *Clydoniceras baluchistanense* (Spath) and *Choffatia* (*Homeoplanulites*) (Spath), a Late Bathonian age of *K. noetlingi* is certain (see also Westermann and Callomon, 1988).

Remarks

Kheraiceras is a stratigraphically important genus of near circum-global distribution. The genus evolved from *Bullatimorphites*, presumably during the Middle Bathonian. It underwent a speciation burst during the Late Bathonian to Early Callovian. After this peak, the genus declined and was reduced to a few stragglers by the Middle and Late Callovian (Hahn, 1969, 1971). Its early radiation was accompanied by a spectacular dispersion of *Kheraiceras* species to almost all biogeographic provinces. The Upper Bathonian of Europe yielded at least seven species including both micro- and macroconchs (Arkell, 1952). Among them, two important macroconchiate species, i.e., *K. hannoveranum* and *K. bullatum* had wide biogeographic distributions. *K. bullatum*, besides Europe, is also reported from Mexico (Westerman *et al.*, 1984; Sandoval *et al.*, 1990), South America (Riccardi *et al.*, 1989) and India (Bardhan *et al.*, 1999). *K. hannoveranum* on the other hand, is so far known to occur only in Europe and India. However, a specimen reported as *'Bullatimorphites* (*Kheraiceras*) *bullatus'* by Sandoval *et al.* (1990, pl. 9, fig. 4a-c) is known from South Mexico. It comes from the Upper Bathonian Steinmanni Zone. It has a marked similarity to the macroconch of Indian *K.* cf. *hannoveranum* (for details see Bardhan *et al.*, 1999). *Bullatimarphites* (*Kheraiceras*) *v-costatus* from the Upper Bathonian of Caracoles, Chile is a large and similarly coarsely ornate form (Riccardi *et al.* 1989, pl. 8, figs. 3, 4). It is larger in size than true *K. bullatum* <M> of Europe and Kutch. Its ribbing is strong, distant and seems to persist on the body chamber for a greater distance and thus agrees more closely with contemporary *K. hannoveranum* of Europe.

Both *K. hannoveranum*, the putative ancestor, and the descendant *K. bullatum* continued to the Lower Callovian beds in Europe. While the former is restricted to the basal Lower Callovian horizon in Southern Germany and the Northern Jura (*Kepplerites keppleri* horizon of Callomon *et al.*, 1988), *K. bullatum* proceeded further up to the *Cadoceras suevicum* fannal horizon of Subtethyan France (Cariou, 1984). Subsequently six new species of *Kheraiceras* appeared during the Early Callovian in these parts of Europe.

This paper describes six species of *Kheraiceras* of which three are new and four are endemic to Kutch and adjoining areas. Besides, Pandey and Westermann (1988) reported another Bathonian species of this genus from Kutch 'island'. The diversity falls in line with the Late Bathonian-Early Callovian radiation of the genus elsewhere, but a high degree of endemism may be attributed to the newly opened-up basin which was yet to establish well developed sea routes with other faunal provinces. Kutch was a pericratonic basin developed at the northwestern margin of the Indian plate with the beginning of fragmentation of Gondwanaland during the Bathonian (Biswas, 1991). The newly formed Kutch basin was immediately occupied by organisms which migrated from other areas and the basin acted as a cradle of evolution. The organisms that migrated here evolved rapidly to colonise the virgin ecospace (Halder, in press) and gave birth to a distinct faunal assemblage unique to India, Madagascar, East Africa and Baluchistan, all of which constitute what is known as the Indo-Madagascan or Ethiopian faunal province. Endemism and speciation events are all pervasive, affecting all major taxa. For example, corals showed a spectacular radiation; about seventy new species appeared in Kutch during Late Bathonian time (Gregory, 1900; Panday and Fürsich, 1993). Many new gastropods (Das *et al.*, 1999), brachiopods (Mukherjee *et al.*, in press) and nautiloids (Halder, in press) originated. Among ammonites, another circum-global genus, *Macrocephalites* Zittel, 1884, was also a product of Bathonian innovation and followed a course of spectacular Late Bathonian-Early Callovian radiation and migration (Datta *et al.*, 1996; Jain *et al.*, 1996). Kutch macrocephalitids are diverse and marked similarly by a high degree of endemism (Spath, 1927–33). However, in both cases, ecologically better adapted species spread to various faunal provinces in a fleeting manner (sensu Ager, 1984) and their first appearances seem to be isochronous everywhere. Such bioevents are of great value in intercontinental chronostratigraphic correlation and in establishing stage boundaries (Callomon, 1993).

The precise place of origin of *Kheraiceras* is unclear. The oldest species known until recently, *K. hannoveranum,* appears to be isochronous everywhere during the Late Bathonian. It is now generally believed that *Kheraiceras* evolved from *Bullatimorphites* through a complex heterochronic process involving neoteny (for details see Bardhan *et al.*, 1994). Evolutionary novelties were introduced, for example, sudden increase in degree of involution, inflation of phragmocone and occlusion of umbilicus by aberrantly-coiled, highly contracted body chamber, etc. (see also Westermann and Callomon, 1988). Two *Kheraiceras* species older than *K. hannoveranum* have been reported from

Kutch. The *Kheraiceras* species from Baluchistan, *K. noetlingi*, is associated with some time-diagnostic ammonites indicating Late (? basal) Bathonian age (Westermann and Callomon, 1988). It is already a fully realised *Kheraiceras* with the synapomorphies (sensu Eldredge and Cracraft, 1980) such as inflated phragmocone, occluded umbilicus, excentrically coiled and contracted body chamber without ribbing towards the aperture. *K. noetlingi* nonetheless still has a *Bullatimorphites*-like large adult size. Unfortunatlely little is known about its inner whorls. Interestingly, inner whorls are *Bulllatimorphites* - like in another Kutch species, *Bullatimorphites* (? *Kheraiceras*) sp. A described from the (?) Middle Bathonian by Pandey and Westermann (1988). It is a remarkable species showing a curious combination of many symplesiomorphies in the early whorls and advanced evolutionary features in the body chamber. If the age assignment is correct, it is the oldest *Kheraiceras* known to date. Hence, in all probability, Kutch is a rare allopatric site (cf. Gould and Eldredge, 1977) where an immigrant ancestor, *Bullatimorphites*, gave rise to *Kheraiceras*. The newly emerged Kutch basin subsequently prompted speciational and migrational events when sea - routes became well established.

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